(12) UK Patent Application (19) GB (11) 2 333 669 (13) A

(43) Date of A Publication 28.07.1999

(21) Application No 9825099.6

(22) Date of Filing 16.11.1998

(30) Priority Data
(31) 09319314 (32) 20.11.1997 (33) JP

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(51) INT CL^6
H04B 1/52, H01P 1/213

(52) UK CL (Edition Q)
H4M MD
H4L LECSX

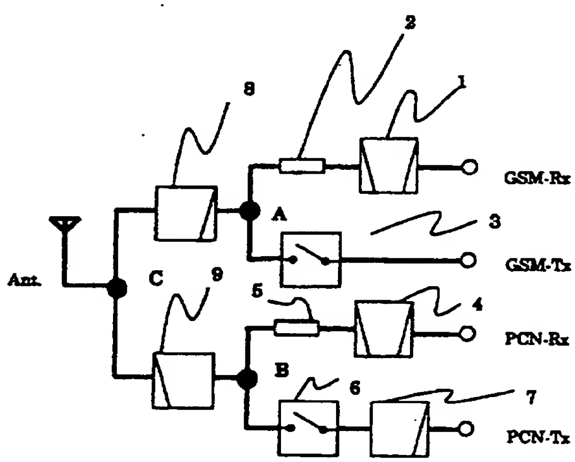
(56) Documents Cited
GB 2257335 A EP 0851526 A2 EP 0818883 A2

(58) Field of Search
UK CL (Edition Q) H4L LECSV LECSX, H4M MD
INT CL^6 H01P 1/213, H04B 1/50 1/52, H04J 3/10
ONLINE ; EPODOC, WPI, JAPIO

(54) Abstract Title
High-frequency circuit device

(57) A high-frequency circuit device comprising: an surface acoustic wave filter which has a pass band corresponding to a reception band and a blocking band corresponding to a transmission band, and in which the absolute value of a reflection coefficient in the transmission band viewed from an input terminal is 0.8 or more; a phase shift circuit for making the input impedance of the surface acoustic wave filter substantially opened in the transmission band; and a RF switch having a bias circuit in which pass loss in the transmission band can be switched in accordance with existence of application of a voltage from an external circuit; wherein one terminal of the phase shift circuit is connected to the input terminal of the surface acoustic wave filter, while the other terminal of the phase shift circuit is connected in parallel with an output terminal of the RF switch at a parallel connection point; and wherein there are provided further three terminals including a terminal formed at the parallel connection point, an output terminal of the surface acoustic wave filter, and an input terminal of the RF switch. By using two sets of such high-frequency circuit devices, it is possible to provide a duplexer for a dual band system, which is small in size, light in weight, and low in cost.

Fig. 1



At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

This print takes account of replacement documents submitted after the date of filing to enable the application to comply with the formal requirements of the Patents Rules 1995

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Fig. 1

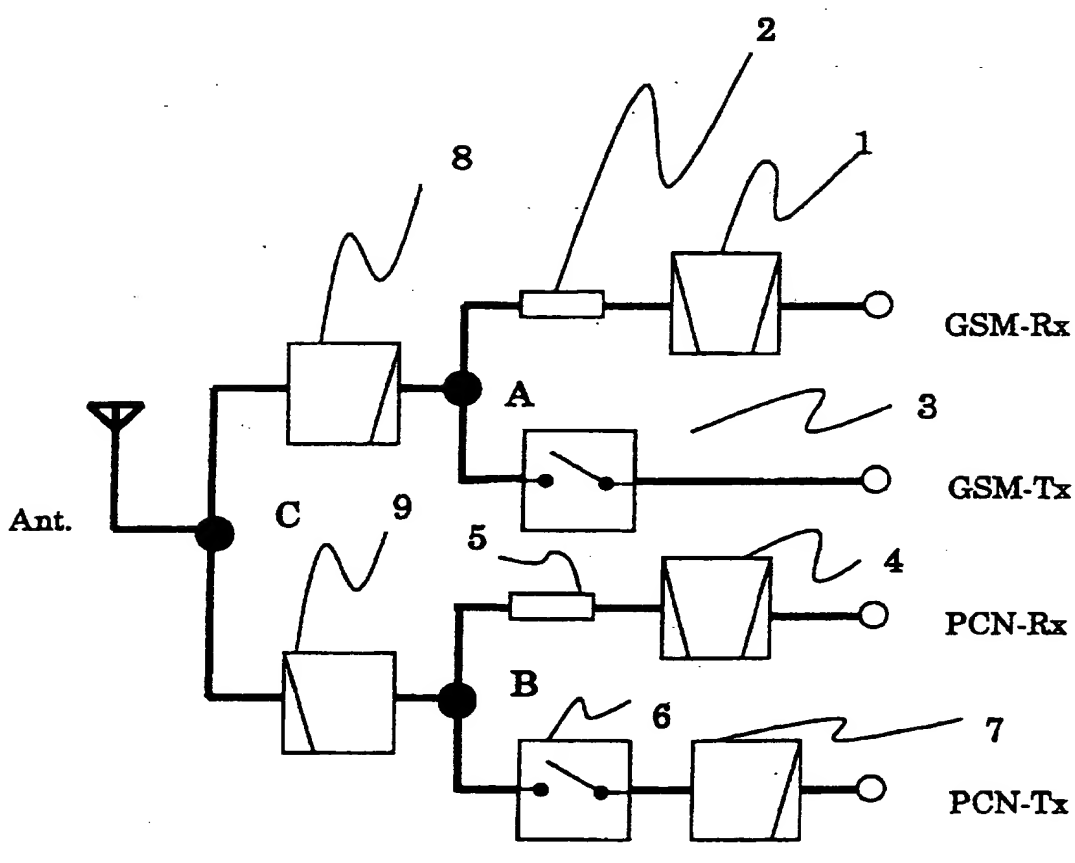


Fig. 2

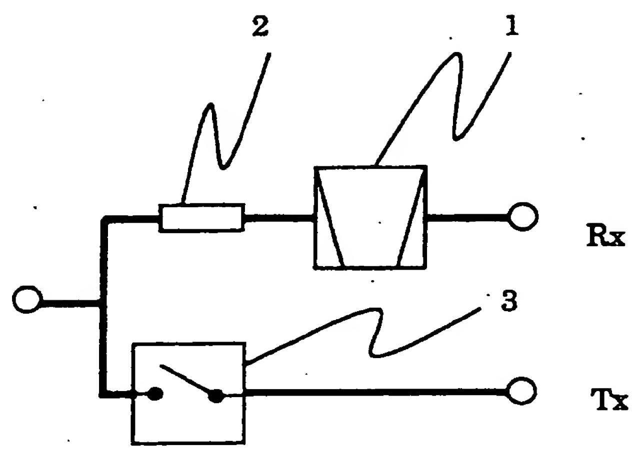


Fig. 3

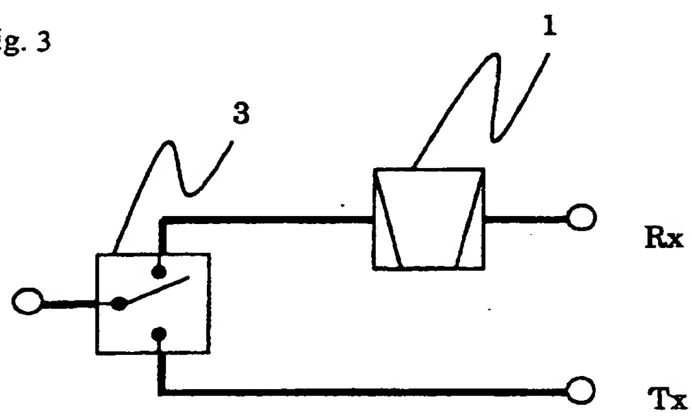
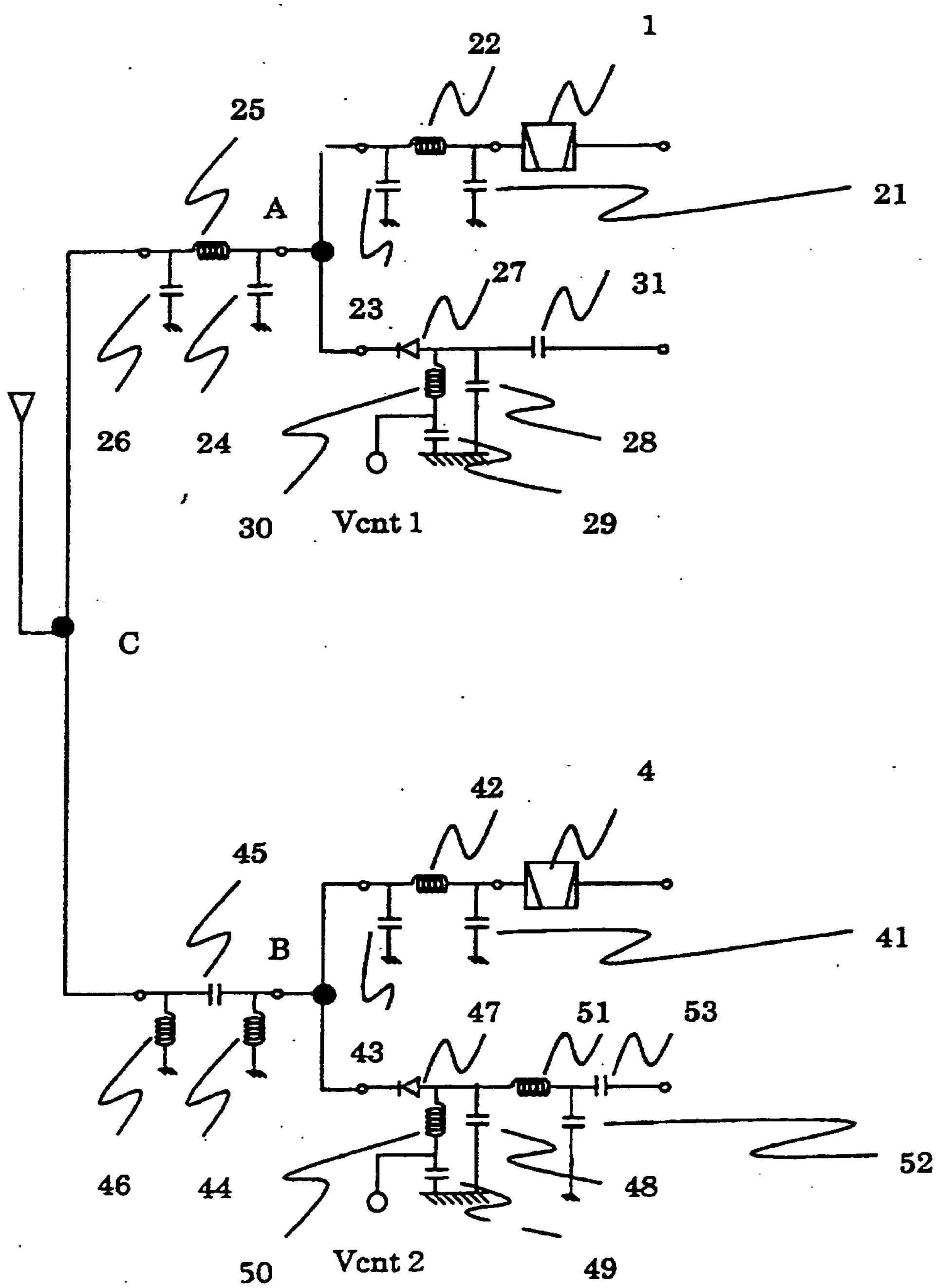


Fig. 4



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HIGH-FREQUENCY CIRCUIT DEVICE

The present invention relates to a high-frequency circuit device, and particularly to a duplexer constituted by an surface acoustic wave filter and a RF switch for use as a mobile communication terminal. A high-frequency circuit device according to the present invention is used mainly for a duplexer for a mobile radio terminal with a so-called dual band operation.

Recently, small-size and light-weight mobile communication terminals represented by pocket telephones have been developed at a high pace. Means for separating a transmission signal and a reception signal from each other is indispensable for a pocket telephone because the pocket telephone employs a single antenna which is used for transmission and reception in common with each other. A duplexer constituted by a dielectric resonator or an surface acoustic wave element has been used in the case of an analog system (FDMA: Frequency Division Multiple Access), while an antenna switch circuit using a RF switch, or a duplexer has been used in the case of a digital system (TDMA: Time Division Multiple Access).

As mobile communication has come into wide use, a frequency band near 2 GHz has been put into practical use in addition to a frequency band of 800 MHz developed at the

beginning. Further, recently, as the number of users has increased suddenly, rapid development of a so-called dual-band terminal in which two or more systems (for example, a GSM (Global System for Mobile Communication) of an 800 MHz and a PCN (Personal Communication System) of a 1.9 GHz band in Europe) can be used in common is demanded because there is a limit in capacity of subscribers in a single system. In a dual-band terminal, a base band circuit or the like can be used in common, but an RF section, particularly a duplexer cannot be used in common.

It is therefore an object of the present invention to address the foregoing problems.

It is another object of the invention to permit means for realizing a duplexer for a dual-band terminal which is smaller in size, lighter in weight, and lower in cost than a conventional duplexer or a duplexer constituted by an antenna switch circuit.

Description will be made below about means for applying a switch of the ON/OFF type which is simpler in structure than a conventional SPDT (Single Pole Dual Throw) switch to a RF switch for transmission. When a RF switch of the ON/OFF type and a reception surface acoustic wave filter are connected in parallel to constitute a duplexer, it is required that the impedance, when the reception surface acoustic wave filter is viewed from the parallel connection point in a transmission band is substantially opened. This is for the purpose of

suppressing the increase of loss with the parallel connection (parallel connection loss) to a minimum. The present invention proposes to make the impedance of the reception surface acoustic wave filter vied from the parallel connection point substantially opened by using a reception surface acoustic wave filter in which the absolute value of a reflection coefficient of an input terminal in a transmission band is 0.8 or more, and a phase shift circuit connected to the input terminal of this reception surface acoustic wave filter. Here "substantially opened" means that the phase of the reflection coefficient becomes about 0 degree within the transmission band when the absolute value of the reflection coefficient is 0.8 or more. If the above-mentioned condition of "substantially opened" is satisfied, it is possible to suppress the parallel connection loss to 0.5 dB or less. By the above-mentioned means, it is possible to realize a duplexer in which an ON/OFF type RF switch and a reception surface acoustic wave filter are connected in parallel.

That is, in order to achieve the above object, according to an aspect of the present invention, provided is a high-frequency circuit device comprising: an surface acoustic wave filter which has a pass band corresponding to a reception band and a blocking band corresponding to a transmission band, and in which the absolute value of a reflection coefficient in the transmission band viewed from an input terminal is 0.8 or more; a phase shift circuit for making the input impedance of the surface acoustic wave filter substantially opened in the

transmission band; and a RF switch having a bias circuit in which pass loss in the transmission band can be switched in accordance with existence of application of a voltage from an external circuit; wherein one terminal of the phase shift circuit is connected to the input terminal of the surface acoustic wave filter, while the other terminal of the phase shift circuit is connected in parallel with an output terminal of the RF switch at a parallel connection point; and wherein there are provided further three terminals including a terminal formed at the parallel connection point, an output terminal of the surface acoustic wave filter, and an input terminal of the RF switch.

In the drawings

Fig. 1 is a block diagram of a dual-band duplexer;

Fig. 2 is a diagram illustrating the structure of a main part of a duplexer according to the present invention;

Fig. 3 is a diagram illustrating the structure of a main part of a duplexer according to conventional technique; and

Fig. 4 is a diagram illustrating an example of the circuit arrangement of a dual-band duplexer.

Embodiments of the present invention will be described with reference to the drawings. Hereinafter, the embodiments will be described specifically on the assumption that a GSM system (transmission: 890-915 MHz, reception: 935-960 MHz) is used as a first transmission/reception band, and a PCN system (transmission: 1,710-1,785 MHz, reception: 1,805-1,880 MHz) is

used as a second transmission/reception band, merely in order to simplify the description.

Fig. 1 is a block diagram illustrating a first embodiment of the present invention, showing an example of the configuration of a duplexer for using both the GSM and PCN systems in common with each other. In the configuration, an surface acoustic wave filter 1 is introduced for GSM reception, in which the reception band of GSM is made to be a pass band with an attenuation property required for the system, while the absolute value of a reflection coefficient of the filter viewed from the input side in the transmission band of GSM is 0.8 or more. One terminal of a phase shift circuit 2 for making the input impedance of the surface acoustic wave filter 1 substantially opened in the transmission band of GSM is connected to an input terminal of the surface acoustic wave filter 1. The other terminal of the phase shift circuit 2 is connected to an ON/OFF type RF switch 3 at a parallel connection point A. An surface acoustic wave filter 4 is introduced for PCN reception, in which the reception band of PCN is made to be a pass band with an attenuation property required for the system, while the absolute value of a reflection coefficient of the filter viewed from the input side in the transmission band of PCN is 0.8 or more. One terminal of a phase shift circuit 5 for making the input impedance of the surface acoustic wave filter 4 substantially opened in the transmission band of PCN is connected to an input terminal of the surface acoustic wave filter 4. The

other terminal of the phase shift circuit 5 is connected to an ON/OFF type RF switch 6 at a parallel connection point B. A low pass filter (LPF) 7 for attenuating harmonic components of a transmission signal with transmission band of PCN as a pass band is connected to the post-stage of the RF switch 6. A low pass filter (LPF) 8 which has a pass band corresponding to the transmission and reception bands of GSM and an attenuation band corresponding to the transmission and reception bands of PCN, and in which the input impedance in the transmission and reception bands of PCN viewed from a parallel connection point C is substantially opened, is connected between the parallel connection point A and the parallel connection point C. On the other hand, a high pass filter (HPF) 9 which has a pass band corresponding to the transmission and reception bands of PCN and an attenuation band corresponding to the transmission and reception bands of GSM, and in which the input impedance in the transmission and reception bands of PCN viewed from the parallel connection point C is substantially opened, is connected between the parallel connection point B and the parallel connection point C. That is, the filters 8 and 9 form a duplexer using the points A, B and C as their terminals. The parallel connection point C is connected to an antenna.

Description will be made below about the operation, at a dual-band time, of the duplexer with such a configuration. Only the ON/OFF type RF switch 3 is turned ON at the time of transmission of GSM. A transmission signal which has arrived at from a transmission circuit of GSM reaches the parallel

connection point A through the ON/OFF type RF switch 3. Since the impedance in the transmission band of GSM of the reception circuit side of GSM viewed from the parallel connection point A is substantially opened, the GSM transmission signal passes the low pass filter (LPF) 8 and reaches the parallel connection point C without travelling onto the reception circuit side of GSM. Since the impedance of the transmission/reception circuit side of PCN viewed from the parallel connection point C is made substantially opened by the high pass filter (HPF) 9, the GSM transmission signal is radiated from the antenna without travelling onto the transmission/reception circuit side of PCN.

Only the ON/OFF type RF switch 6 is turned ON at the time of transmission of PCN. A transmission signal which has arrived at from a transmission circuit of GSM reaches the parallel connection point B through the ON/OFF type RF switch 6. Since the impedance in the transmission band of PCN of the reception circuit side of PCN viewed from the parallel connection point B is substantially opened, the PCN transmission signal passes the high pass filter (HPF) 9 and reaches the parallel connection point C without travelling onto the reception circuit side of PCN. Since the impedance of the transmission/reception circuit side of GSM viewed from the parallel connection point C is made substantially opened by the low pass filter (LPF) 8, the PCN transmission signal is radiated from the antenna without travelling onto the transmission/reception circuit side of GSM.

At the time of reception, both the ON/OFF type RF switches 3 and 6 are turned OFF, so that the impedances of the respective transmission circuit sides viewed from the parallel connection points A and B become substantially opened. Therefore, reception signals in both the GSM and PCN bands which have arrived at the antenna are separated from each other by the low pass filter (LPF) 8 and the high pass filter (HPF) 9. The reception signal of GSM reaches the parallel connection point A, while the reception signal of PCN reaches the parallel connection point B. The respective reception signals pass the corresponding surface acoustic wave filters 1 and 4 without travelling on the corresponding transmission circuit sides. After unnecessary components are eliminated by the filters, the reception signals are supplied to the corresponding reception circuits, respectively. With respect to a transmission signal of GSM, the low pass filter 8 suppresses harmonic components contained in the GSM transmission signal and no low pass filter is required to be provided in the preceding stage of the ON/OFF type RF switch 3.

Next, the superiority of the present invention will be described by use of Figs. 2 and 3. Fig. 2 is a diagram of the configuration of the present invention illustrating only the portion between the parallel connection point A and the respective terminals of the transmission and reception circuits in Fig. 1. Fig. 3 shows an example of the configuration according to the conventional technique. In either diagram, a lower pass filter for suppressing harmonic

components in a transmission signal is omitted merely for the sake of simplification. As is apparent from the comparison of Fig. 2 with Fig. 3, a so-called SPDT (Single Pole Dual Throw) type switch having two outputs for one input is required in the configuration according to the conventional technique in order to eliminate the influence of the reception circuit at the time of transmission. On the other hand, in the configuration according to the present invention in which the phase shift circuit 2 is provided, a simple ON/OFF type RF switch can be employed because the impedance of the reception filter 1 is substantially opened in the transmission frequency. The ON/OFF type switch can be constituted by one transistor, one FET or one diode at the minimum, while at least two or more transistors, FETs or diodes are required to constitute the SPDT type switch. Thus, it is possible to constitute the ON/OFF type switch in a smaller size and at a lower price than the SPDT type switch.

Next, using a more detailed circuit diagram of Fig. 4, description will be made about of the dual-band duplexer shown by the block diagram in Fig. 1. A phase shift circuit (corresponding to the phase shift circuit 2 in Fig. 1) is constituted by an inductor 22 and capacitors 21 and 23, and connected between the surface acoustic wave filter 1 and the parallel connection point A. A bias circuit is constituted by an inductor 30 and a capacitor 28, and DC blocking capacitors 29 and 31 are connected to the bias circuit. The bias circuit with the DC blocking capacitors 28 and 31 is connected to the

parallel connection point A through a PIN diode 27 so as to form a parallel circuit with the circuit constituted by the phase shift circuit and the surface acoustic wave filter 1. When constants of the bias circuit constituted by the inductance 30 and the capacitance 28 are set to cause parallel resonance in the transmission frequency of GSM, it is possible to avoid the influence of the bias circuit in the transmission signal frequency. In the same manner as above, a phase shift circuit (corresponding to the phase shift circuit 5 in Fig. 1) is constituted by an inductor 42 and capacitors 41 and 43, and connected between the parallel connection point B and the surface acoustic wave filter 4. A bias circuit is constituted by an inductor 50 and a capacitor 48. A low pass filter (corresponding to the low pass filter 7 in Fig. 1) is constituted by an inductor 51 and a capacitor 52 (partially contributed by the capacitor 48). DC blocking capacitors 49 and 53 are connected to the bias circuit and the low pass filter. The circuit constituted by the bias circuit, the low pass filter and the DC blocking capacitors is connected to the parallel point B through a PIN diode 47 so as to form a parallel circuit with the circuit constituted by phase shift circuit and the surface acoustic wave filter 4. A low pass filter constituted by an inductor 25 and capacitors 24 and 26 is connected between the parallel point A and the parallel point C. This low pass filter has a pass band in the transmission and reception bands of GSM and has an attenuation band in the transmission and reception bands of PCN, and the

impedance of this low pass filter viewed from the parallel connection point C is made substantially opened in the transmission and reception bands of PCN. A high pass filter constituted by inductors 44 and 46 and a capacitor 25 is connected between the parallel point B and the parallel point C. This high pass filter has a pass band in the transmission and reception bands of PCN and has an attenuation band in the transmission and reception bands of GSM, and the impedance of this high pass filter viewed from the parallel connection point C is made substantially opened in the transmission and reception bands of PCN. Generally, the parallel connection point C is made to be a connection point with an antenna. Bias terminals Vcnt1 and Vcnt2 are led out from the connection point between the inductor 30 and the capacitor 29 constituting one bias circuit and the connection point between the inductor 50 and the capacitor 49 constituting the other bias circuit as illustrated. If control voltages for switching are applied to the bias terminals Vcnt1 and Vcnt2, it is possible to control the ON/OFF of the RF switch.

Although an example in which the bias circuits 28, 29, 30, 48, 49 and 50 for the RF switch are constituted by lumped element circuits providing parallel resonance are shown in Fig. 4, it is obvious that the influence of bias terminals can be avoided even if used is a distributed element line in which the electrical length at the transmission signal frequency is about a quarter of the wavelength of the transmission signal frequency.

Further, as for the phase shift circuit for making the input impedance of the surface acoustic wave filter in the transmission band substantially opened, though that which is constituted by a lumped element circuit is shown in Fig. 4 by way of example, the phase shift circuit may be constituted by a distributed element circuit of a proper length.

With the above-mentioned configuration, it is possible to realize a dual-band duplexer using two transmission/reception bands, in a small size and at a low price. Further, it is obvious that the configuration of the present invention can be extended for a triple-band duplexer using three or more transmission/reception bands.

According to the configuration of the present invention, the input impedance of the reception circuit side viewed from a parallel connection point is substantially opened. Accordingly, it is possible to use a RF switch with a simple configuration constituted by one PIN diode and a bias circuit at the minimum on the transmission side. It is therefore possible to make the circuit small-sized and low-priced.

CLAIMS

1. A high-frequency circuit device comprising:

an surface acoustic wave filter having a pass band which is a reception signal band and having a blocking band which is a transmission signal band, the absolute value of a reflection coefficient in said transmission signal band viewed from an input terminal of said surface acoustic filter being 0.8 or more;

a phase shift circuit for making the input impedance of said surface acoustic wave filter substantially opened in said transmission signal band; and

an RF switch having a bias circuit in which pass loss in said transmission signal band can be switched in accordance with existence of application of a voltage from an external circuit;

wherein one terminal of said phase shift circuit is connected to said input terminal of said surface acoustic wave filter, while the other terminal of said phase shift circuit is connected to an output terminal of said RF switch.

2. A high-frequency circuit device according to Claim 1, wherein said phase shift circuit is constituted by a concentrated constant element constituted by an inductance element and a capacitance element.

3. A high-frequency circuit device according to Claim 1, wherein said bias circuit is constituted by a concentrated constant element constituted by an inductance element and a capacitance element.

4. A high-frequency circuit device according to Claim 1, wherein said phase shift circuit is a distributed element circuit.

5. A high-frequency circuit device according to Claim 1, wherein said bias circuit is a circuit including a distributed element line having an electrical length which is equal to a quarter of signal wavelength.

6. A high-frequency circuit device comprising:

a first surface acoustic wave filter having a pass band which is a first reception signal band and having a blocking band which is a first transmission signal band, the absolute value of a reflection coefficient in said first transmission signal band viewed from an input terminal of said first surface acoustic wave filter being 0.8 or more;

a first phase shift circuit for making the input impedance of said first surface acoustic wave filter substantially opened in said first transmission signal band;

a first RF switch having a bias circuit in which pass loss in said first transmission signal band can be controlled in accordance with existence of application of a voltage from an external circuit;

a second surface acoustic wave filter having a pass band which is a second reception signal band and having a blocking band which is a second transmission signal band, the absolute value of a reflection coefficient in said second transmission signal band viewed from an input terminal of said second surface acoustic wave filter being 0.8 or more;

a second phase shift circuit for making the input impedance of said second surface acoustic wave filter substantially opened in said second transmission signal band;

a second RF switch having a bias circuit in which pass loss in said second transmission signal band can be controlled in accordance with existence of application of a voltage from an external circuit; and

a low pass filter having a pass band which is the first reception signal band and the first transmission signal band, and having a blocking band which is the second reception signal band and the second transmission signal band;

a high pass filter having a pass band which is the second reception signal band and the second transmission signal band, and having a blocking band which is the first reception signal band and the first transmission signal band;

wherein one terminal of said first phase shift circuit is connected to said input terminal of said first surface acoustic wave filter, while the other terminal of said first phase shift circuit, an output terminal of said first RF switch and one terminal of said low pass filter are connected to each other;

wherein one terminal of said second phase shift circuit is connected to said input terminal of said second surface acoustic wave filter, while the other terminal of said second phase shift circuit, an output terminal of said second RF switch and one terminal of said high pass filter are connected to each other; and

wherein the other terminal of said low pass filter and the other terminal of said high pass filter are connected to each other.

7. A high-frequency circuit device according to Claim 6, wherein said first or second phase shift circuit is constituted by a concentrated constant element constituted by an inductance element and a capacitance element.

8. A high-frequency circuit device according to Claim 6, wherein said first or second bias circuit is constituted by a concentrated constant element constituted by an inductance element and a capacitance element.

9. A high-frequency circuit device according to Claim 6, wherein said first or second phase shift circuit is a distributed element circuit.

10. A high-frequency circuit device according to Claim 6, wherein said first or second bias circuit includes a distributed element line having an electrical length which is equal to a quarter of signal wavelength.